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HOW CORPORATE PENSIONS AFFECT STOCK RETURNS: THE ROLE OF R&D EXPENDITURES

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We examine the stock return implications of corporate-defined benefit pension plans in innovative U.S. firms and in R&D- and patent-sorted portfolio specifications. We find that investors underreact to firms increasing off-balance-sheet liabilities. Pensions represent material off-balance-sheet liabilities: in our extensive and large sample (1985–2017, 2541 firms for 26,522 observations), entities with pension plans are 38% more levered when we integrate pension liabilities and assets into the firms' capital structure. We find that R&D-intensive firms increasing the size of their pension liability subsequently underperform their benchmark returns. Through six alternative R&D-market capitalization portfolios, we also find that this association is stronger for smaller firms. Finally, the relationship remains persistent over a long horizon. These findings are robust to endogeneity concerns addressed through instrumental variables, propensity score matching, and Heckman correction.

Keywords: Stock returns; R&D expenditures; D.B. pension schemes; leverage; off-balance sheet items.

JEL Classifications: G23, G30, G32, H32, O33

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1. Introduction

Off-balance-sheet items are a potential source of additional risk exposure for firms: their reporting opacity creates informative gaps for investors and higher costs of information asymmetry[a] (Lin *et al.* 2019). Several studies examine the effects of information asymmetry on the choice of corporate capital structures, investments, and stock returns (Fazzari *et al.* 1987, Diamond 1991, Berger *et al.* 2005), while the empirical evidence on off-balance-sheet items remains limited.

This paper explores the link between corporate pensions and stock returns on a large cross-section of U.S. firms for the period 1985–2017, using innovative firms as a distinct channel.

Firms' decision to increase capital investments has both positive and negative consequences. Titman *et al.* (2004) showed that investment expenditure results in favorable stock returns if investors believe in growth opportunities and management's intention to put firms' interests ahead of their own. We consider R&D expenditures as a particular case (Li 2011) for firms sponsoring defined benefit (D.B.) pension plans for two reasons. First, R&D firms represent a large section of the U.S. stock market and play a vital role in long-run economic development. Second, the commitment to both R&D and pension plans is inflexible and requires significant financial resources. This critical resource allocation choice allows us to consider this as an ideal set-up to investigate pension plans' impacts on stock returns.

Corporate pension obligations show similarities with long-term debt, and their increase may lead to stock underperformance over a long period. However, the adverse market reaction reasons differ from those of debt offerings and point to information asymmetry costs. This is because accounting for pension obligations, especially in D.B. plans, involves significant discretion and informative opaqueness (Lin *et al.* 2019, Shivdasani & Stefanescu 2010): Investors may believe that the firm is destroying value (Jensen 1986).

We contribute to the literature by presenting empirical evidence of D.B. corporate pension plans' stock return implications for R&D-sorted portfolios. We show that investors do not appreciate allocating funds to pensions in R&D-intensive firms. Given the less flexibility of R&D expenditures (Li 2011), we document a negative relationship, more pronounced for high R&D firms, in two sorted R&D specifications (Croce *et al.* 2019) and through IV-GMM regressions.

We provide evidence of a robust interaction effect between sponsoring D.B. plans and the level of R&D intensity on a firm's stock returns. Applying the Fama & MacBeth (1973) two-step regression procedure for two-sorted R&D portfolios further confirms our main finding. We obtain similar results from both Fama–French three and five-factor models.

Finally, our results are robust to various alternative portfolio measures and Heckman selection bias corrections. Since many firms do not report their R&D

[a] Coleman *et al.* (2006) found that agency costs are higher in for-profit pension funds making the plan sponsors entities subject to more information asymmetry problems than the non-sponsoring firms.

expenses, we use patent data (Stoffman *et al.* 2019) as a robustness check, with similar results. Our findings are consistent with the prediction that investors react negatively to increases in D.B. plans' size, and effects are persistent in the long run (Loughran & Ritter 1995, Spiess & Affleck-Graves 1999).

The rest of the paper is as follows. Section 2 discusses the literature and develops our hypotheses. Section 3 discusses the sample construction and variable selection. Section 4 presents our methodology and provides our baseline findings. Section 5 assesses the robustness of our findings, and finally, Sec. 6 concludes the paper.

2. Literature Review and Hypotheses Development

Corporate pension plans are significant off-balance sheet items with material financial and economic implications. As of 2016, the value of private-sector D.B. pension plan assets was estimated at 2.923 trillion,[b] the largest off-balance-sheet item for U.S. corporate firms.[c]

Off-balance sheet items create asymmetric information due to their reporting opacity (Blankley & Swanson 1995, Amir & Benartzi 1998, Bergstresser *et al.* 2006, Brown & Wilcox 2009, Chuk 2013). Chan *et al.* (2001) found that the market is pessimistic about the prospect of poorly performing R&D-intensive stocks and expects that returns should be higher than low R&D firms.

R&D-intensive firms and D.B. plan sponsoring firms represent a considerable portion of the U.S. capital market. However, unlike other capital expenditures, R&D investments are less flexible. Firms' inability to raise enough funds to finance R&D projects sends bad signals to the market, as investors presume that their competitive edge may be lost (Li 2011).

A large body of literature reports that R&D-intensive firms (Hall & Lerner 2010, Czarnitzki & Hottenrott 2011a,b, Li 2011) are exposed to more financial constraints because of asymmetric information. Cai *et al.* (2020) found the evidence that financially weaker firms are more likely to default on their pension obligations. Davis & De Haan (2012) documented that the small and unprofitable firms face more underfunding problems. Ghilarducci & Sun (2006) found that D.B. plan sponsors incur more pension costs, implying a greater vulnerability to financial constraints. Thus, exploring the relationship between stock returns and D.B. pension obligations concerning firm-level R&D expenditures is relevant for investors and firms.

Pension plan beneficiaries have claims on sponsoring firms similar to debtholders (Anantharaman & Lee 2014). However, beneficiaries consider their claim as a retirement fund ("something"), whereas sponsoring companies may underestimate ("nothing") the current weight of their future obligations (Treynor *et al.* 1976). The pension fund directly impacts firms' internal financial resources, especially if they are

[b] Private Pension Plan Bulletin Historical Tables and Graphs 1975–2016, Employee Benefits Security Administration, United States Department of Labor.

[c] Contribution Plan Profile: A Close Look at 401(k) Plans, BrightScope and Investment Company Institute, 2014.

financially constrained. Additionally, stockholders of financially constrained firms have the incentive to increasingly underfund pension plans in favor of risky investment projects (Clark & Monk 2006). If these are successful, stockholders gain, while plan beneficiaries suffer losses in the alternative scenario. This risk-shifting behavior arises from the debt-like claim of pension beneficiaries (Lin *et al.* 2019, Pedersen 2019).

A higher leverage ratio (on- or off-balance sheet) signals an increased risk exposure. Pension obligations are collateralized by pension plan assets and backed by the Pension Benefit Guaranty Corporation — PBGC (Sharpe 1976, Ippolito 1985). Although incentives for risk-taking differ for private and public plan sponsors (Atanasova & Gatev 2013), bankruptcy costs for employees of D.B. plan sponsors are, in general, lower than for debtholders. At the same time, the Employee Retirement Income Security Act of 1974 (ERISA) requires firms with PBOs exceeding pension assets to cover the shortfall through cash contributions within 7 years: this further worsens D.B. plan sponsors' financial constraints and increases the cost of capital (Lin *et al.* 2019).

Jin *et al.* (2006) documented that despite the accounting opacity, capital markets' informal efficiency leads to adequate pricing of pension plan risks. However, D.B. plans negatively affect takeovers through their long-term uncertainty (Cocco & Volpin 2013). Kisser *et al.* (2017) found that U.S. corporate D.B. plan managers strategically use pension regulations and accounting measures to lower the plan's reported liabilities by approximately 10%. Bodie *et al.* (1987) documented an inverse relationship between plan sponsors' profitability and discount rates. Ghicas (1990) showed that different accounting methods lead to varying levels of conservatism of pension estimates, with lower ones being associated with a higher probability of default.

D.B. plan participants do not act like senior lenders as their claims are backed by ERISA protection, while creditors, due to lack of information, hardly include pension liability-related risks in debt contracts (Rauh 2006). Billett *et al.* (2007) showed that the firms' level of information asymmetry has a determining effect on their debt maturity structure: pension plan sponsoring leads to more short-tenure debt because of higher information asymmetry.

Stockholders may consider D.B. plans as threats to their payouts (Armitage & Gallagher 2019). Thus, stockholders lack incentives to minimize pension funding gaps. Shareholders find it reasonable to divert D.B. plan assets to riskier investments, especially when a firm approaches financial distress (Rauh 2006). Managers may experience conflicts of interest: stockholders attempting to minimize incentive gaps and align risk preferences may offer managers equity compensation (Anantharaman & Lee 2014).

Therefore, we expect a negative association between corporate pension liabilities and stock performance, especially when high R&D firms are considered.

Hypothesis 1: *R&D intensive firms increasing their corporate pension liabilities are associated with poorer stock performance compared to low R&D firms.*

Despite small innovative firms' critical role in the economy, a number of studies (f.i. Carpenter & Petersen 2002, Hennessy & Whited 2007) document that they are subject to increased information asymmetry due to uncertainty about their ability to undertake positive NPV projects. This suggests that they are more susceptible to financial constraints (Li 2011).

We, therefore, expect the following hypothesis to hold.

Hypothesis 2: *Small R&D-intensive firms increasing their corporate pension liabilities are associated with more unsatisfactory stock performance compared to low-R&D firms.*

3. Data and Methodology

3.1. *Data and sample*

To test the relationship between the increase in pension obligations and stock returns, we use Compustat annual fundamentals and pension data to construct our firm-level variables. Compustat pension data include SEC filings reports for domestic and international pension assets and liabilities (Rauh 2006). Monthly stock and index returns are obtained from CRSP: following Titman *et al.* (2004), we exclude firms if monthly returns for one or more months are missing in a fiscal year. As in Franzoni & Marin (2006), we drop ADRs, REITS, and units of beneficial interest from our sample. All variable definitions and measures are presented in the appendix.

Our dataset starts in 1985 since it represents the earliest date with pension data in Compustat. Following Shivdasani & Stefanescu (2010), we exclude regulated utilities firms (SIC:4000-4999) and financial firms (SIC: 6000-6999). Besides, we drop firms with missing or non-positive assets and sales.

We follow the Financial Accounting Standards Board (FASB) rule 1975 for reporting R&D expenditures (Croce *et al.* 2019). We form our stock returns portfolio based on firms' R&D intensity: following Li (2011), we consider two specifications: R&D expenditure and R&D capital. R&D expenditure is measured as the firms' annual reported R&D expenditure divided by the total assets (R&D/AT), as in (Croce *et al.* 2019). We calculate R&D capital (RDC) with Eq. (1), using the 5 years weighted average R&D/AT, and considering a 20% depreciation rate for the annual expenditure (Chan *et al.* 2001, Cocco & Volpin 2013).

$$\mathrm{RDC}_{it} = \mathrm{R\&D}_{it} + 0.8 * \mathrm{R\&D}_{it-1} + 0.6 * \mathrm{R\&D}_{it-2} + 0.4 * \mathrm{R\&D}_{it-3} + 0.2 * \mathrm{R\&D}_{it-4}. \quad (1)$$

The (unreported) correlation between these two measures of R&D is about 0.98. Following Croce *et al.* (2019), we sort firms into quintile portfolios based on market capitalization to remove the effects of illiquid stocks. The quintile approach allows us to measure the impact of top and bottom 20% stocks, while the 60% intermediate stocks form the middle range group.

Our final sample includes 26,522 firm-year observations with 2541 pension sponsoring firms between 1985 and 2018. About 37.32% of plan sponsor firm-year observations have missing R&D expenditure in our sample. This leaves us with 16,625 observations (1607 firms) to construct quintile portfolios with approximately 3325 items in the top 20% and bottom 20% quintiles.

3.2. *Dependent, treatment, and control variables*

The main dependent variable is the cumulative excess returns (CER) where $\text{CER}_{t\to t+J} := \sum_{j=1}^{J} \text{CER}_{t+j}$ is the J horizon ahead CERs (Croce *et al.* 2019). In the 6-intersection portfolio analysis, we use CER_t as our dependent variable.

The treatment variable (Pension Size) is calculated as the projected benefit obligations divided by total debt plus projected benefit obligation, PBO/(PBO + TOTAL DEBT). Compustat item *pbpro* provides the present values of all the actuarial benefits plus the future projected benefits for employees. We assume that increased PBO levels induce more information asymmetry and negatively affect market returns. A few studies use accumulated benefit obligations (ABO – Bodie 1990, Lin *et al.* 2019), representing liabilities already incurred from benefits earned by employees from years of service and salaries. Ippolito (1985) showed that given the implied characteristics of pension obligations, PBO is a more appropriate measure since it considers the current effect of future changes in pension obligations, hence should be reflected in stock returns.

Finally, we use two sets of control variables: pension variables and firm characteristics.

Carroll & Niehaus (1998) discussed firms' risk exposures from pension liabilities. To capture the effects of firm-specific pension risk on stock returns, following the study of Rauh (2006), we calculate the funding status by subtracting the pension plan assets from PBO and then dividing the result by PBO. The absolute value of *underfunding/assets* takes a value of 1 when the funding status is less than 0 and 0 otherwise.

We use additional firm characteristics as control variables consistently with corporate pension plans, capital structure, and stock returns literature. Following the study of Kisser *et al.* (2017), we construct *consolidated leverage*, which investors consider an essential element for measuring the firms' cost of equity (Jin *et al.* 2006). *Firm size* is calculated as the logarithm of each firm's market value and is chosen to reflect firm-specific risks (Reinganum 1982). We use *Assets maturity* (calculated as the gross value of PPE divided by total assets times PPE divided by the annual depreciation expense, plus the current assets divided by total assets times current assets divided by the cost of goods sold) to capture the effects of maturity mismatches between assets and financial obligations (Myers 1977). We calculate *Earnings volatility* as the 3-year standard deviation of EBITDA divided by the average assets for that period to analyze the volatility in firms' cash flows.

R&D-intensive firms, being more financially constrained, should therefore pay fewer dividends: we, therefore, include the *Dividend yield* variable (dividends scaled by the firm's equity market value). We calculate *leverage* as the total debt divided by the equity market value (Diamond 1991). *Market-to-book value* (M/B) is calculated as the firm's market value divided by the book value of the firm's total assets (Myers 1977). Following Brockman *et al.* (2010), we calculate the *Z-score* dummy to reflect firms' credit quality, taking a value of 1 for scores above 1.81 and 0 otherwise. Finally, *tangibility* is the share of firms' investments in the gross PPE scaled by total assets.

3.3. *Model specification and methods*

3.3.1. *Baseline model specification*

To formally evaluate the implications of corporate-defined benefit pension plans in innovative U.S. firms in R&D and patent-sorted portfolio specifications, we start with the following univariate regression equation.

$$\mathrm{CER}_{t\to t+J} = \alpha_0 + \alpha_1 \times \left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right)_{it} + \varepsilon_{it}, \tag{2}$$

where $\mathrm{CER}_{t\to t+J}$ is the J-years ahead cumulative excess returns. For robustness, we include both value- and equal-weighted returns. We report excess returns over the benchmark value- and equal-weighted returns results from the top 20% (HIGH R&D Expense or Capital) and bottom 20% (HIGH R&D Expense or Capital) portfolios.

3.3.2. *Fama–MacBeth and Fama–French factor regressions*

Although Eq. (2) explains the relationship between returns and pension size, we do not control for firm characteristics that may bias estimations. We, therefore, adopt a Fama–MacBeth (F.M.) two-step regression (Fama & MacBeth 1973), as described in Eq. (3).

The F.M. model is built as follows:

$$\mathrm{CER}_{t\to t+J} = \gamma_0 + \gamma_1 \times \hat{\beta}_i\left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right) + \sum \gamma_i \hat{\beta}' X + \varepsilon_i, \tag{3}$$

where $\mathrm{CER}_{t\to t+J}$ is the J-years ahead cumulative excess returns, X is the vector of firm control variables such as firm size (Lsize), market-to-book (M/B), return on assets (ROA), tangibility, assets maturity, *Z-score* dummy, earnings volatility, dividend yield, the pension funding status, and the consolidated leverage. γ_i are the loadings from estimated $\hat{\beta}'$ from the first step of F.M.

To control for factor risk, we use Fama–French three and five factor models (Eq. (4)).

$$\mathrm{CER}_{t\to t+J} = \alpha_0 + \alpha_1 \times \left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right)_{it} + \sum \delta' F_t + \varepsilon_{it}, \tag{4}$$

where F_t are the Fama–French factors[d] (3 and 5 factors, respectively, Fama & French 1993, 2015) linear regression results for the top and bottom 20% of two sorted

[d] Data for Fama-French factor models are obtained from Kenneth R. French — Data Library (https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html).

R&D portfolios. HML is the return difference between a high (top 30%) book-to-market diversified portfolio and a low (bottom 30%) book-to-market diversified portfolio. SMB is the return difference between the small-size stock (bottom 50%) and big-size stock (top 50%). R_{MKT} is the market return factor based on a market portfolio. R_{MW} is the return difference between a diversified portfolio with robust and weak profitability. R_{CMA} is based on the return difference between diversified portfolios with high investment and low investment opportunities.

3.3.3. *GMM approach*

To address potential endogeneity issues, as in Croce *et al.* (2019), we develop the following modified instrument:

$$IV = \beta(J)[1 + \gamma(\mathrm{RD}_{j,t} - \overline{\mathrm{RD}}_t)],$$

where $\mathrm{RD}_{j,t}$ and $\overline{\mathrm{RD}}_t$ are Fama–French 12 industries mean and overall-mean R&D intensity, respectively. Using this instrument, we estimate Eq. (5) to fit the GMM regression, thus obtaining a heteroskedasticity-corrected robust model:

$$\mathrm{CER}_{t\to t+J} = \alpha_0 + \beta_1 \times \left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right)_{it} + \sum \varphi' Z_{it} + v_i + \eta_j + \varepsilon_{it}, \qquad (5)$$

where the dependent variable $\mathrm{CER}_{t\to t+J}$ is the J-years forward cumulative excess returns, while Z_{it} is the vector of firm control variables.

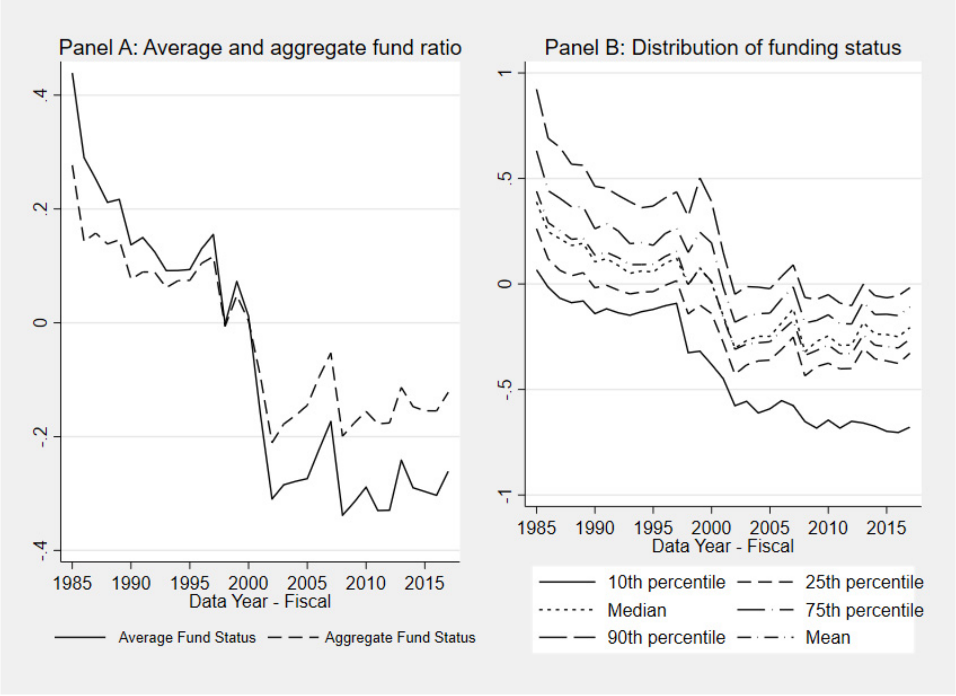
4. Empirical Analysis

4.1. *Funding status of sample firms*

To present the U.S. firms' overall funding status, we calculate the average and aggregate pension underfunding for the period 1985–2017 (Fig. 1, Panel A).

We calculate the aggregate underfunding status using the cross-sectional summation of each year's funding ($pplao_t - pbpro_t$) divided by the total sum of pension liabilities ($pbpro_t$). Instead, average underfunding is calculated using each year's ratio of the underfunding status to pension liabilities. The difference between the two ratios was at its lowest in the period 1985–2001. Historically, the absolute average pension underfunding was lower than the aggregate funding status until the year 2000.

Figure 1 (Panel B) presents the distribution of pension underfunding with several breakpoints in the period 1985–2017. Rauh (2006) found that underfunding occurs with low-interest rates, but adversity is lower if fixed income assets are greater. A fund with pension underfunding must allocate sufficient funds to fill a portion of the funding shortfall plus newly created pension liabilities from the previous year (Langbein *et al.* 2006). The pension Protection Act of 2006 (PPA-2006) tightened the funding cut for the plan sponsors that paid into PBGC.



Notes: This figure shows the evolution of the funding status (the difference between projected benefits obligations and pension plan assets, divided by projected benefit obligations) in Panel A, and its distribution in Panel B.

Fig. 1. Average, aggregate and distribution of funding status, 1985–2017.

The figure shows that while the aggregate underfunding ratio outweighed the average funding ratio, the pension underfunding quartile distribution remained similar.

4.2. *Summary statistics*

Table 1 presents the summary statistics of D.B. plan sponsor firms.

Benchmark-adjusted CER is 1.8% and −0.05%, respectively, for the value- and equally-weighted alternatives for firms that do not report R&D expenditure. For the R&D expenditure reporting firms, annual CER value- and equally-weighted returns are 3.8% and 2.1%, respectively. Positive R&D firms witness more excess returns than those that do not report R&D expenditure.

Our two sorted R&D portfolios (R&D expenditure and capital) report higher CER for top 20% portfolios than the bottom 20% portfolios. High-R&D firms are more exposed to higher information asymmetry and are expected to pay a higher premium. Consistent with the literature (Chan *et al.* 2001, Croce *et al.* 2019), the top 20% R&D expensed firms generate 50% more value-weighted CER than the bottom 20% R&D expensed firms.

Table 1. Summary statistics.

Mean	Non-R&D firms	All R&D firms with R&D/AT > 0	LOW R&D Exp	HIGH R&D Exp	LOW R&D Cap	HIGH R&D Cap
CER-value weighted	0.018	0.038	0.026	0.039	0.025	0.045
CER-equal weighted	(0.001)	0.021	0.007	0.023	−0.001	0.021
Consolidated leverage	0.294	0.262	0.281	0.190	0.280	0.200
Underfunding/assets	0.016	0.026	0.016	0.023	0.021	0.029
PBO/(PBO+total debt)	0.291	0.413	0.283	0.429	0.317	0.458
Funding status	(0.078)	(0.106)	(0.113)	(0.177)	(0.130)	(0.191)
Divided yield	0.019	0.018	0.019	0.013	0.020	0.013
Assets maturity	12.552	9.566	12.567	7.205	13.302	7.349
Earnings volatility	0.033	0.031	0.028	0.040	0.027	0.037
Leverage	0.234	0.173	0.222	0.120	0.212	0.119
Market-to-book ratio	1.505	1.728	1.456	2.122	1.490	2.166
ROA	0.133	0.139	0.128	0.140	0.131	0.146
Lsize	7.431	7.875	7.979	7.683	8.278	8.018
Tangibility	0.715	0.590	0.707	0.498	0.737	0.501
Z-score indicator	0.832	0.909	0.867	0.928	0.883	0.930
Number of observations	9897	14,879	3353	3272	2396	2283
Number of firms	1190	1416	520	528	355	333

Notes: This table presents the summary statistics of our main variables for R&D expenditures and R&D capital measures from quintile-sorted portfolios for different subsamples of our dataset. Variables are defined and described in the Appendix. All variables are winsorized at the 1st and 99th percentiles.

Consolidated leverage is higher for low-R&D firms: it rises from 22.20% to 28.10% when we incorporate pension liabilities into leverage calculation. For high-R&D firms, such change is about 58.33%. Overall, pension plan sponsors are 38% more levered when we integrate pension liabilities and assets. High-R&D firms are smaller, have a high market-to-book ratio, and face greater information asymmetry problems.

Pension underfunding for R&D-intensive firms is 2.3% compared to 1.6% for low-R&D firms. R&D-intensive firms are growth firms with more investment opportunities and more cash needs. The temporal trade-off between the pension fund allocation and growth opportunities motivates them to keep plans more underfunded relative to mature firms with low-R&D activities.

Non-R&D reporting firms have more dividend yield, asset maturity, earnings volatility, leverage, and tangibility. This finding is consistent with the existing literature (Datta *et al.* 2005, Coleman *et al.* 2006, Brockman *et al.* 2010, Lin *et al.* 2019, Pedersen 2019).

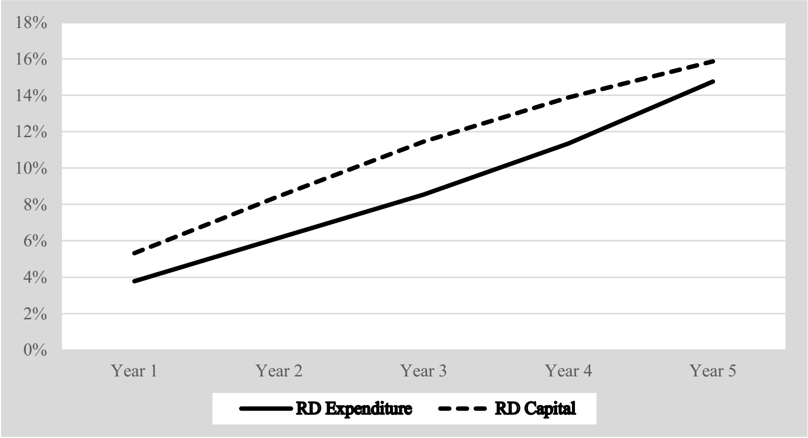
Table 2 (Panel A) reports CER and their mean differences for the top and bottom 20% portfolios (implied HML-R&D). Consistent with prior research (Chan *et al.* 2001, Croce *et al.* 2019), we find that R&D-intensity is linked with higher average CER, and the difference is statistically significant. Our results hold if we consider top and bottom 10% portfolios (unreported, available upon request).

Figure 2 visualizes the mean difference between high and low innovative firms (top and bottom 20%). With the increase in horizons, the expected excess return difference increases.

Table 2. Summary statistics for R&D sorted portfolios.

Long-run returns and volatilities										
	R&D expense sorted portfolios					R&D capital sorted portfolios				
Horizons	1	2	3	4	5	1	2	3	4	5
Returns	Cumulative excess return — Value weighted					Cumulative excess return — Value weighted				
Low	0.052	0.088	0.128	0.167	0.210	0.047	0.079	0.114	0.159	0.206
High	0.090	0.149	0.214	0.281	0.358	0.101	0.164	0.228	0.298	0.364
Diff.	0.038**	0.062***	0.085***	0.113***	0.148***	0.053***	0.085***	0.115***	0.139***	0.159***
	Cumulative excess return — Equal weighted					Cumulative excess return — Equal weighted				
Low	0.014	0.023	0.036	0.044	0.054	−0.003	0.003	0.013	0.033	0.048
High	0.058	0.096	0.139	0.178	0.225	0.056	0.097	0.141	0.189	0.222
Diff.	0.044***	0.073***	0.104***	0.134***	0.171***	0.058***	0.093***	0.128***	0.156***	0.174***
	Low R&D					High R&D				
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Year 2	0.805*					0.783*				
Year 3	0.686*	0.860*				0.675*	0.841*			
Year 4	0.624*	0.770*	0.894*			0.614*	0.750*	0.878*		
Year 5	0.566*	0.708*	0.816*	0.915*		0.567*	0.686*	0.795*	0.895*	
PBO/(PBO+ Total Debt)	0.001	−0.024	−0.045	−0.056*	−0.067*	−0.092*	−0.105*	−0.133*	−0.135*	−0.1594*

Notes: This table shows, in Panel A, the summary statistics for double sorted R&D expenditure and R&D capital portfolios (High, Low — as the top or bottom 20% firms) as well as their difference (Diff.) in terms of cumulated excess returns, both equal- and value-weighted over 5 years. Standard errors are reported in the parenthesis. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote significance levels. Panel B reports the pair-wise correlation between the pension size ratio and the cumulative excess equal-weighted returns over 5 years, where * indicates significance at the 1% level.



Notes: This figure visualizes the mean difference between high and low innovation firms. High and Low R&D firms are the top and bottom 20% calculated from double-sorted R&D portfolios. Both the R&D expenditure and the R&D capital measures are plotted.

Fig. 2. Cumulative excess return difference between high and low innovation firms.

Table 3. Corporate defined benefit pension and returns to innovation.

	R&D expenditure					R&D capital				
Horizon (J)	1	2	3	4	5	1	2	3	4	5
					Equally weighted					
Low R&D	0.012	−0.038	−0.091	−0.122*	−0.153*	0.046	0.016	0.001	−0.057	−0.093
	(0.041)	(0.051)	(0.060)	(0.070)	(0.078)	(0.047)	(0.057)	(0.067)	(0.077)	(0.087)
R^2	0.000	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.001
High R&D	−0.194***	−0.276***	−0.402***	−0.464***	−0.571***	−0.209***	−0.298***	−0.433***	−0.535***	−0.593***
	(0.037)	(0.046)	(0.055)	(0.064)	(0.071)	(0.044)	(0.055)	(0.067)	(0.080)	(0.093)
R^2	0.009	0.012	0.055	0.021	0.029	0.010	0.015	0.023	0.027	0.027
HML-R&D	−0.206***	−0.238**	−0.311**	−0.343**	−0.418**	−0.255***	−0.314***	−0.434***	−0.478***	−0.450***
χ^2	8.93	6.00	5.98	4.70	4.79	9.19	7.88	9.13	7.19	5.27
Obs.	6293	5790	5320	4885	4477	4455	4089	3729	3384	3061
					Value weighted					
Low R&D	0.002	−0.075	−0.160**	−0.220***	−0.283***	−0.003	−0.066	−0.090	−0.166*	−0.219**
	(0.045)	(0.056)	(0.068)	(0.078)	(0.088)	(0.051)	(0.063)	(0.075)	(0.086)	(0.098)
R^2	0.000	0.001	0.002	0.003	0.005	0.000	0.001	0.001	0.002	0.003
High R&D	−0.197***	−0.269***	−0.388***	−0.436***	−0.545***	−0.187***	−0.268***	−0.388***	−0.465***	−0.522***
	(0.038)	(0.048)	(0.057)	(0.066)	(0.072)	(0.045)	(0.056)	(0.067)	(0.080)	(0.093)
R^2	0.009	0.011	0.018	0.018	0.025	0.008	0.011	0.018	0.021	0.021
HML-R&D	−0.199***	−0.194*	−0.228*	−0.217	−0.262	−0.184**	−0.202*	−0.299*	−0.299	−0.302
χ^2	7.17	3.34	2.67	1.56	1.57	4.48	2.95	3.81	2.52	1.71
Obs.	6293	5790	5320	4885	4477	4455	4089	3729	3384	3061

Notes: This table shows the univariate OLS regression equation of cumulative excess returns over five different time horizons and the Pension size ratio. We report excess returns over the benchmark value-weighted and equal-weighted return results from the top 20% (HIGH R&D expense or capital) and bottom 20% (HIGH R&D expense or capital) portfolios. HML-R&D expense and R&D capital are implied portfolios. We measure innovation intensity as the R&D expenditure and R&D capital divided by the total assets, respectively. Standard errors are reported in the parenthesis. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

The correlation matrix in Table 2 (Panel B) depicts how, as the horizon increases, a monotonically increasing negative relationship between the pension size ratio and returns occurs. The negative relationship between equally weighted excess returns in horizon five and the pension size ratio is 73.20% higher than horizon 1 for high R&D firms.

4.3. *Univariate analysis*

Table 3 presents the univariate OLS regression from Eq. (2).

The significant coefficients of the R&D sorted portfolios are negative, and the relationship is stronger for the top 20% R&D sorted portfolios. The coefficients for the top 20% extreme R&D capital sorted portfolios are −0.21 and −0.18 for value- and equally-weighted CER, respectively.

Similar results hold for the R&D expenditure portfolios. We observe that returns for implied HML-R&D portfolios differ significantly with negative coefficients, showing that high R&D firms realize lower stock returns, provided that they are D.B. plan sponsors. These findings remain significant across all five horizons for both value- and equally-weighted returns. This relationship supports our hypothesis that the negative excess returns-pension size relationship is more pronounced in the high R&D firms. We do not obtain significant results for low quintile R&D firms.

4.4. *Multivariate analysis*

Table 4 presents the results of the multivariate analysis.

In Panel A, we report the horizon-specific coefficients [$\beta_1(1)$, $\beta_1(2)$, $\beta_1(3)$, $\beta_1(4)$, $\beta_1(5)$] of the pension size variable for the top and bottom 20% R&D portfolios from Eq. (3). Results show that $B_1(J)$ estimates are statistically significant at a 1% level and monotonically decreasing over the horizon only for high R&D firms (robust for both R&D expenditure- and capital-sorted portfolios). Over the five horizons, the pension size ratio coefficients for equally-weighted excess returns report significant compounded negative growth. The reported R^2 increases with the increase in the horizon. We do not observe a statistically significant relationship for low R&D firms.

Thus, we conclude that an increase in the pension size for R&D-intensive firms tends to underachieve the benchmark stock returns over the following 5 years. Our results are potentially related to Titman *et al.* (2004), who show that firms with more abnormal capital investments underperform the benchmark stock returns over a 5-year horizon. Such a negative association is independent of the risk-return dynamics of firm characteristics. Franzoni & Marin (2006) showed that since the information opacity related to pension liabilities is very high, investors cannot anticipate the long-term underperformance of firms.

In fact, the long-term return reversal (De Bondt & Thaler 1985) and post-equity issuance anomaly (Loughran & Ritter 1995) explanations are insufficient to understand the negative relationship in full. Thus, our empirical analysis reveals that D.B.

Table 4. Corporate defined benefit pensions and returns to innovation.

Panel A: Fama–MacBeth regression.

	Dependent variable: CEW				Dependent variable: CVW			
Variables	LOW R&D EXP	HIGH R&D EXP	LOW R&D CAP	HIGH R&D CAP	LOW R&DEXP	HIGH R&D EXP	LOW R&D CAP	HIGH R&D CAP
B1(1)	−0.016	−0.116***	(0.023)	−0.135***	−0.018	−0.125***	(0.023)	−0.151***
	(0.052)	(0.039)	(0.060)	(0.049)	(0.053)	(0.040)	(0.061)	(0.050)
Avg. R^2	0.231	0.270	0.246	0.314	0.229	0.270	0.247	0.315
B1(2)	−0.06	−0.203***	−0.162	−0.200**	−0.065	−0.214***	−0.195	−0.217***
	(0.066)	(0.041)	(0.133)	(0.073)	(0.067)	(0.043)	(0.151)	(0.078)
Avg. R^2	0.231	0.266	0.261	0.301	0.229	0.264	0.261	0.301
B1(3)	−0.07	−0.303***	−0.115	−0.304***	−0.087	−0.314***	−0.14	−0.322***
	(0.077)	(0.058)	(0.108)	(0.073)	(0.079)	(0.060)	(0.109)	(0.075)
Avg. R^2	0.236	0.283	0.260	0.303	0.234	0.284	0.261	0.305
B1(4)	−0.060	−0.367***	−0.103	−0.410***	−0.076	−0.380***	−0.146	−0.422***
	(0.080)	(0.051)	(0.121)	(0.075)	(0.081)	(0.052)	(0.129)	(0.076)
Avg. R^2	0.238	0.272	0.254	0.286	0.234	0.274	0.254	0.288
B1(5)	−0.017	−0.426***	−0.097	−0.402***	−0.034	−0.438***	−0.134	−0.410***
	(0.096)	(0.051)	(0.121)	(0.099)	(0.098)	(0.056)	(0.125)	(0.105)
Avg. R^2	0.239	0.275	0.270	0.301	0.235	0.273	0.267	0.305

Panel B: Fama–French 3 factor model.

	LOW R&D EXP	HIGH R&D EXP	Low-High (χ^2)	LOW R&D CAP	HIGH R&D CAP	Low-High (χ^2)
Panel B(1): CEW						
B1(1)	0.033	−0.158***	0.191	0.051	−0.200***	0.251
	(0.048)	(0.047)	(8.21)	(0.058)	(0.061)	(8.860)
B1(2)	−0.025	−0.240***	0.215	0.025	−0.293***	0.318
	(0.068)	(0.065)	(5.22)	(0.076)	(0.081)	(8.160)

Table 4. (*Continued*)

Panel B: Fama–French 3 factor model.

	LOW R&D EXP	HIGH R&D EXP	Low-High (χ^2)	LOW R&D CAP	HIGH R&D CAP	Low-High (χ^2)
B1(3)	−0.095	−0.370***	0.275	0.014	−0.420***	0.434
	(0.090)	(0.084)	(5.05)	(0.099)	(0.102)	(9.230)
B1(4)	−0.126	−0.433***	0.307	−0.035	−0.519***	0.484
	(0.113)	(0.101)	(4.06)	(0.127)	(0.123)	(7.490)
B1(5)	−0.157	−0.509***	0.352	−0.056	−0.586***	0.530
	(0.137)	(0.119)	(3.76)	(0.155)	(0.150)	(6.060)
Panel B(2): CVW						
B1(1)	0.021	−0.153***	0.174	0.020	−0.184***	0.204
	(0.049)	(0.046)	(6.65)	(0.059)	(0.061)	(5.750)
B1(2)	−0.06	−0.220***	0.160	−0.030	−0.254***	0.224
	(0.073)	(0.065)	(2.71)	(0.079)	(0.082)	(3.850)
B1(3)	−0.155	−0.351***	0.196	−0.047	−0.375***	0.328
	(0.098)	(0.084)	(2.32)	(0.107)	(0.104)	(4.860)
B1(4)	−0.215*	−0.400***	0.185	−0.113	−0.447***	0.334
	(0.126)	(0.101)	(1.32)	(0.140)	(0.121)	(3.240)
B1(5)	−0.272*	−0.478***	0.206	−0.161	−0.505***	0.344
	(0.155)	(0.117)	(1.12)	(0.174)	(0.148)	(2.270)

Panel C: Fama–French 5 factor model and momentum.

	LOW R&D EXP	HIGH R&D EXP	Low-High (χ^2)	LOW R&D CAP	HIGH R&D CAP	Low-High (χ^2)
Panel B(3): CEW						
B1(1)	0.027	−0.153***	0.180	0.048	−0.197***	0.245
	(0.047)	(0.047)	(7.39)	(0.057)	(0.060)	(8.72)
B1(2)	−0.03	−0.230***	0.200	0.021	−0.283***	0.304
	(0.068)	(0.065)	(4.60)	(0.075)	(0.080)	(7.60)
B1(3)	−0.102	−0.366***	0.264	0.005	−0.419***	0.424
	(0.089)	(0.083)	(4.65)	(0.098)	(0.102)	(8.98)

Table 4. (*Continued*)

Panel C: Fama–French 5 factor model and momentum.

	LOW R&D EXP	HIGH R&D EXP	Low-High (χ^2)	LOW R&D CAP	HIGH R&D CAP	Low-High (χ^2)
B1(4)	−0.134	−0.427***	0.293	−0.046	−0.518***	0.472
	(0.112)	(0.101)	(3.76)	(0.125)	(0.123)	(7.23)
B1(5)	−0.164	−0.505***	0.341	−0.069	−0.585***	0.516
	(0.137)	(0.119)	(3.55)	(0.154)	(0.151)	(5.73)
Panel B(4): CVW						
B1(1)	0.016	−0.148***	0.164	0.02	−0.176***	0.196
	(0.049)	(0.046)	(5.98)	(0.058)	(0.061)	(5.45)
B1(2)	−0.055	−0.218***	0.163	−0.028	−0.246***	0.218
	(0.072)	(0.065)	(2.83)	(0.079)	(0.082)	(3.71)
B1(3)	−0.147	−0.353***	0.206	−0.044	−0.371***	0.327
	(0.098)	(0.084)	(2.57)	(0.106)	(0.103)	(4.88)
B1(4)	−0.206	−0.402***	0.196	−0.111	−0.450***	0.339
	(0.125)	(0.101)	(1.50)	(0.139)	(0.121)	(3.37)
B1(5)	−0.264*	−0.480***	0.216	−0.159	−0.505***	0.346
	(0.155)	(0.117)	(1.23)	(0.174)	(0.148)	(2.29)

Notes: This table shows the time-series average slopes from the Fama–MacBeth regression equation in Panel A and the Fama–French three and five factors linear regression equation in Panel B. We report the regression coefficients for the Pension size ratio only (PBO/(PBO+Total debt)). The top and bottom 20% innovative firms represent the top and bottom quintiles of the double-sorted R&D portfolios. Standard errors are reported in the parentheses. Chi-square in parentheses for Low-High in Panel B and Panel C. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

plan sponsors with higher R&D are exposed to greater negative returns, independently from the long-term return reversal and risk characteristics of the firms.

Panel B offers the results for the top and bottom 20% R&D portfolios using Eq. (4). Our independent variable is the pension size ratio, as we hypothesize a negative relationship between the pension size and stock returns. Results are identical to panel A. We find that $B_1(J)$ estimates are statistically significant at the 1% level and monotonically decreasing over the horizon only for high R&D firms (robust for both R&D expenditure and capital specifications). We do not observe statistically significant relationships for low R&D firms.

These findings reassert that pension benefit obligations of D.B. sponsored plans have significant explanatory power on stock returns underperformance when incorporated into total liabilities.

4.5. *Cross-section in GMM*

Equation (5) allows us to decompose the predictive power of pension size over the horizons $\beta(J)$. Table 5 presents the IV-GMM regression results (second stage), adjusted for the firm (υ_i), and year (η_j) fixed effects. We cluster standard errors by firms and report them in parentheses.

We confirm our earlier findings. In particular, we show that $B_1(J)$ estimates are statistically significant and monotonically decreasing over the horizon only for high R&D firms (robust for both R&D expenditure and capital specifications).

Like coefficients in Tables 3 and 4, the low-R&D firms' stock returns-pension size are statistically insignificant and do not have a strict monotonic pattern. Our main argument holds: among pension plan sponsors, R&D-intensive firms tend to underperform the benchmark adjusted returns. This differentiation channel is the heterogeneous impact of information asymmetry for these two groups (Li 2011).

4.6. *2-by-3 portfolio analysis*

In this section, similarly to Li (2011), we construct a 2-by-3 portfolio at the end of year t by sorting RD/AT into two groups and market capitalization (EMV) into three groups. Their intersection creates six RD/AT-EMV portfolios that are reconstructed every year and investigated through Eq. (6):

$$\mathrm{CER}_{t\to t+J} = \beta_0 + \beta_1\left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right) + \delta' X_{it} + \varphi' Z_{it} + \upsilon_i + \phi_j + \eta_j + \varepsilon_{it}, \quad (6)$$

where $\mathrm{CER}_{t\to t+J}$ is the J-years ahead cumulative excess returns. X_{it} is the vector of firm control variables, Z_{it} is the vector of portfolio intersections, and $\upsilon_i, \phi_j, \eta_j$ represent a firm, year, and industry fixed effects. The cumulative excess returns are value- and equally-weighted, respectively. Once more, we measure innovation intensity as the R&D expenditure and capital.

Results are provided in Table 6. The intersections among the top 20% R&D firms and the small market cap results are significant at the 1% level. Intersections among

Table 5. Defined benefit plans and returns to innovation — GMM analysis.

	Dependent variable: CEW				Dependent variable: CVW			
Variables	LOW R&D EXP	HIGH R&D EXP	LOW R&D CAP	HIGH R&D CAP	LOW R&D EXP	HIGH R&D EXP	LOW R&D CAP	HIGH R&D CAP
B1(1)	−0.012	−0.471**	−0.066	−0.321	−0.031	−0.488**	−0.099	−0.311
	(0.200)	(0.187)	(0.222)	(0.223)	(0.209)	(0.195)	(0.231)	(0.231)
Adj R^2	0.019	0.015	0.013	0.023	0.018	0.013	0.012	0.023
Hansen J (P-value)	0.187	0.592	0.156	0.453	0.195	0.397	0.165	0.352
B1(2)	−0.229	−0.800***	0.056	−0.535**	−0.241	−0.793***	0.053	−0.499*
	(0.263)	(0.232)	(0.292)	(0.267)	(0.274)	(0.239)	(0.303)	(0.273)
Adj R^2	0.01	−0.02	0.01	0.02	0.01	−0.01	0.01	0.02
Hansen J (P-value)	0.292	0.667	0.262	0.374	0.967	0.616	0.281	0.249
B1(3)	−0.399	−1.175***	0.118	−0.691**	−0.42	−1.158***	0.138	−0.602*
	(0.330)	(0.277)	(0.352)	(0.322)	(0.344)	(0.283)	(0.363)	(0.327)
Adj R^2	0.00	−0.04	0.01	0.03	0.01	−0.03	0.01	0.03
Hansen J (P-value)	0.417	0.890	0.688	0.618	0.431	0.604	0.673	0.416
B1(4)	−0.322	−1.489***	−0.066	−1.125***	−0.316	−1.474***	−0.036	−1.021**
	(0.398)	(0.319)	(0.402)	(0.395)	(0.416)	(0.325)	(0.416)	(0.400)
Adj R^2	0.01	−0.07	0.01	0.01	0.02	−0.06	0.01	0.03
Hansen J (P-value)	0.849	0.719	0.776	0.599	0.822	0.417	0.745	0.355
B1(5)	−0.434	−1.900***	−0.29	−1.486***	−0.420	−1.880***	−0.264	−1.354***
	(0.455)	(0.357)	(0.442)	(0.494)	(0.474)	(0.362)	(0.455)	(0.499)
Adj R^2	0.01	−0.11	0.01	−0.01	0.02	−0.10	0.01	0.02
Hansen J (P-value)	0.833	0.667	0.462	0.412	0.768	0.357	0.474	0.218

Notes: This table shows the results (second stage) from the instrumental variable GMM (IV-GMM) regression. Our instrumental variable is calculated as the difference between R&D expenditure or capital and the time-series average values, as in Croce *et al.* (2019). Regression results are adjusted for the firm, year, and Fama–French 12 industry fixed effects. The top and bottom 20% innovative firms represent the top and bottom quintile of the double-sorted R&D portfolios. We report regression coefficients for the Pension size ratio only (PBO/(PBO+Total debt)). Standard errors are clustered by firms and reported in parenthesis. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels. In IV-GMM, R-squared adjusted is no longer bounded between 0 and 1.

the top 20% R&D specifications and small market cap groups are more significant for R&D expense than for capital specifications. The underperformance of the benchmark returns for the positive R&D firms is less than for all R&D firms. Finally, the underperformance of equally-weighted excess returns is lower.

These findings suggest that small firms with R&D investments sponsoring D.B. plans underperform the benchmark stock returns. Thus, in support of the second hypothesis, we show that market size plays a significant role in stock returns for firms with D.B. plan sponsorship and R&D returns. Firms in low RDC and the big market capitalization group tend to underperform the benchmark returns at the 10% significance level. The findings of this 2-by-3 portfolio analysis suggest that the negative stock returns-pension size relationship is aggravated for smaller firms.

Table 6. Portfolio analysis.

	Equal weighted		Value weighted	
	R&D	R&D > 0	R&D	R&D > 0
Low R&D exp, Small	−0.094**	−0.062**	−0.111***	−0.073***
	(0.039)	(0.026)	(0.042)	(0.027)
Low R&D exp, Mid	0.006	−0.004	0.007	−0.004
	(0.030)	(0.020)	(0.032)	(0.021)
Low R&D exp, Big	−0.025	−0.019	−0.034	−0.022
	(0.036)	(0.025)	(0.037)	(0.025)
HIGH R&D EXP, Small	−0.142***	−0.154***	−0.149***	−0.167***
	(0.049)	(0.053)	(0.050)	(0.054)
HIGH R&D EXP, Mid	0.027	0.019	0.033	0.022
	(0.030)	(0.030)	(0.031)	(0.031)
HIGH R&D EXP, Big	0.012	0.021	0.004	0.014
	(0.029)	(0.030)	(0.030)	(0.030)
LOW R&D CAP, Small	−0.031	−0.066***	−0.041	−0.076***
	(0.043)	(0.024)	(0.044)	(0.025)
LOW R&D CAP, Mid	−0.032	−0.009	−0.031	−0.01
	(0.032)	(0.019)	(0.033)	(0.020)
LOW R&D CAP, Big	−0.043	−0.044*	−0.05	−0.050**
	(0.033)	(0.023)	(0.032)	(0.023)
HIGH R&D CAP, Small	−0.223***	−0.255***	−0.241***	−0.272***
	(0.082)	(0.086)	(0.085)	(0.089)
HIGH R&D CAP, Mid	0.055	0.042	0.063*	0.048
	(0.036)	(0.037)	(0.037)	(0.038)
HIGH R&D CAP, Big	0.053	0.053	0.051	0.051
	(0.033)	(0.034)	(0.034)	(0.035)

Notes: This table presents results obtained from portfolios constructed based on two R&D-sorted and three market capitalization-sorted groups. We report the regression coefficients for the Pension size ratio only. The groups' intersection forms six R&D-Market cap portfolios held for next year and rebuilt every year. The cumulative excess returns are value-weighted and equal-weighted, respectively. We measure innovation intensity as the R&D expense and R&D capital divided by the total assets, respectively. Standard errors are clustered by firms and reported in parenthesis. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

4.7. *Matching estimates*

Descriptive statistics in Table 1 indicate that high and low R&D firms vary in many dimensions. To overcome this concern, we employ a propensity-matching analysis. Our treatment group is based on high R&D firms (top 20%), and the control group holds low R&D firms (bottom 20%). We include covariates as in Eq. (3) and control for year and two-digit SIC codes. Results are strongly consistent with our previous findings and confirm that the observed association between pension size and returns is unlikely to be due to omitted variables.

Table 7 reports the average treatment effect of the treatment for value- and equally-weighted CER in Panels A and B, respectively.

Table 7. Matching estimates based on treatment and control firms matched by propensity score.

Outcome variable	Horizon 1	Horizon 2	Horizon 3	Horizon 4	Horizon 5
Panel A: Cumulative excess return (value weighted)					
Four nearest neighbors with common support	−0.036***	−0.067***	−0.077***	−0.077***	−0.103***
	[3.13]	[4.59]	[4.67]	[4.01]	[4.85]
Radius matching (caliper = 0.05)	−0.030***	−0.055***	−0.069***	−0.072***	−0.101***
	[2.61]	[3.84]	[4.15]	[3.71]	[4.73]
Local linear regression (Bandwidth = 0.5)	−0.028***	−0.046***	−0.067***	−0.078***	−0.107***
	6.190	[6.19]	[6.33]	[4.90]	[6.03]
Panel B: Cumulative excess return (equal weighted)					
Five nearest neighbors with common support	−0.030***	−0.059***	−0.075***	−0.071***	−0.088***
	[2.78]	[4.42]	[4.86]	[4.04]	[4.53]
Radius matching (caliper = 0.05)	−0.024***	−0.050***	−0.063***	−0.063***	−0.091***
	[2.26]	[3.78]	[4.03]	[3.54]	[4.62]
Local linear regression (Bandwidth = 0.5)	−0.025***	−0.045***	−0.064***	−0.073***	−0.100***
	[2.59]	[5.63]	[6.31]	[4.64]	[5.89]
Firm-controls	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the average treatment effect of the treated for cumulative excess return (value-weighted) and cumulative excess return (equal-weighted) in Panel A and Panel B, respectively. We employ three matching models. Model 1 is based on five nearest neighbors and Mahalanobis distance covariate matching. Model 2 uses radius matching within 0.05 caliper. Model 3 uses local linear regression matching with bandwidth 0.5. Each model includes a full set of covariates used in the baseline equation (3). T-statistics for respective matching estimates are reported in the parenthesis. Definitions and measurements of all the variables used in this study are provided in the Appendix along with data sources. We winsorize all the nonbinary firm-level variables at 1% level. Financial firms [SIC:6000-6999] and utilities firms [SIC:4900-4999] are excluded following the prior studies. Statistical significance is donated by *, **, and *** to indicate the significance level at 10%, 5%, and 1%, respectively.

We employ three matching models. Model 1 is based on five nearest neighbors and Mahalanobis distance covariate matching. Model 2 uses radius matching within 0.05 caliper. Model 3 uses local linear regression matching with bandwidth of 0.5. All differences between treatment and control groups are significant at the 1% level. Together, all models suggest that high R&D and D.B. plan sponsor firms substantially underperform benchmarks over longer horizons.

5. Selection Bias and Robustness

Although our results remained consistent across all specifications, ignoring non-sponsors may be prone to self-selection bias. To address this concern, we follow Shivdasani & Stefanescu (2010) and use a three equations system method that adjusts for self-selection bias:

$$\mathrm{PS}^{+}_{i,t} = \alpha_0 + \alpha_1 \times \gamma_{i,j,t} + \sum \alpha'_2 X_{i,j,t} + \zeta_{i,t}, \qquad (7)\ \text{[Self-SelectionEquation]}$$

$$\mathrm{PS}_{i,t} = 1 \text{ if } \mathrm{PS}^{+}_{i,t} > 0, \quad \text{and 0 otherwise}, \qquad (7^*)$$

$$\left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right)_{i,t} = \gamma_0 + \gamma'_1 \times R_{i,t} + \xi_{i,t}, \qquad (8)\ \text{[PensionBenefitsEquation]}$$

$$\mathrm{CER}_{i,t} = \alpha_0 + \alpha_1 \times \text{Predicted}\left(\frac{\mathrm{PBO}}{\mathrm{PBO} + \text{total debt}}\right)_{i,t} + \sum \delta' Z_{i,j,t} + \upsilon_i + \eta_t + \varepsilon_{i,t}. \qquad (9)$$

Equation (7) addresses how firms self-select to become sponsors as we jointly estimate pension choice (Eq. (7)) and pension size (Eq. (8)). The implied variable (7*) $\mathrm{PS}^{+}_{i,t} > 0$ estimates if the expected net benefit of pension sponsorship is positive: we assume that a firm would become a sponsor only if it is beneficial (pension sponsorship equals 1 when $\mathrm{PS}^{+}_{i,t} > 0$ and 0 otherwise), but this element is unobservable. For sponsors, the Heckman selection model estimates Eqs. (7) and (8). The predicted value from the above two-step regression process is then used in Eq. (9) to estimate the stock returns-pension size relationship.

We incorporate the additional *Union* variable as an instrument in the self-selection model (Lin *et al.* 2019) since it is uncorrelated with pension size but may influence a firm's decision to sponsor D.B. plans (Shivdasani & Stefanescu 2010). Data are collected from the Current Population Survey[e] for 2001–2017 as the percentage of employed workers represented by unions.

D.B. plans to motivate employees to work in a firm for an extended period and reduce workforce turnover (Mitchell 1982): Pension plans are investments in human capital. Still, employees' benefits increase fast as employees stay longer with the firm. Therefore, we incorporate the *Employee tenure* variable in Eq. (8), proxied by the median tenure of workers with the current employers by two-digit codes within The North American Industry Classification System (NAICS) from the U.S. Bureau of Labor Statistics.[f]

At the final stage of the selection bias correction model, we estimate Eq. (9) as a treatment-effects model. We bootstrap the reported standard errors to eliminate the correlation of residuals. Finally, in Table 8, we provide descriptive statistics to analyze sponsors and non-sponsors before presenting the estimations from Eqs. (7)–(9).

D.B. plan sponsors are, on average, 24.84% larger than non-sponsors, have lower market-to-book ratios, higher ROA, low leverage, similar values for tangibility, better *Z-score*, lower earnings volatility, higher dividend yield, less employee

[e] Source: U.S. Bureau of Labor Statistics: https://www.bls.gov/news.release/union2.t03.htm.
[f] Economic News Release (tenure) at https://www.bls.gov/news.release/tenure.t05.htm.

Table 8. Characteristics of pension sponsors and non-sponsors.

	Panel A — Difference t-test: Sponsors–Non-sponsors					
Mean	Non-R&D firms	All R&D firms with R&D/AT > 0	LOW R&D EXP	HIGH R&D EXP	LOW R&D CAP	HIGH R&D CAP
Panel A: Descriptive statistics.						
CER eq. w.	0.023***	0.044***	0.009	0.032**	−0.003	0.005
CER value w.	0.022***	0.049***	0.012	0.044	−0.001	0.021
Lsize	1.596***	2.343***	1.673***	2.799***	1.655***	2.557***
Market-to-book	−0.042***	−0.576***	−0.143***	−0.738***	−0.152***	−0.627***
ROA	0.034***	0.161***	0.012***	0.309***	0.003	0.233***
Leverage	−0.01***	0.039***	−0.004	−0.004	0.000	−0.011***
Tangibility	0.025***	0.158***	0.062***	0.099***	0.036***	0.091***
Assets maturity	0.802***	2.148***	1.971***	0.494*	1.303***	0.261
Z-score	0.083***	0.118***	0.04***	0.204***	0.021*	0.205***
Earnings vol.	−0.022***	−0.048***	−0.013***	−0.067***	−0.008***	−0.052***
Dividend yield	0.005***	0.009***	0.007***	0.007***	0.007***	0.009***
Tenure	0.004***	0.003***	0.005***	0.003***	0.006***	0.003***
Union	0.008***	0.001***	0.013***	−0.004***	0.014***	−0.003***

Panel B: Industry adjusted return.

	FF12	FF30	FF48	SIC2	SIC3	STD 5YRS
Cumulative excess return — Value weighted						
Non-sponsor	0.007	−0.007	−0.007	−0.008	−0.005	0.498
Sponsor	0.015	0.015	0.014	0.016	0.010	0.362
Difference	0.008***	0.021***	0.020***	0.024***	0.016***	−0.136***
Cumulative excess return — Equal weighted						
Non-sponsor	−0.007	−0.006	−0.006	−0.008	−0.005	0.462
Sponsor	0.015	0.014	0.013	0.015	0.010	0.343
Difference	0.022***	0.021***	0.020***	0.023***	0.016***	−0.119***

Notes: This table compares firm characteristics between the pension sponsors and non-sponsors. All variables, except the Fama–French factors, are winsorized at the 1st and 99th percentiles. Variable definitions are provided in the Appendix. Panel A tabulates the mean differences between sponsors and non-sponsors and the t-statistics. Panel B presents the cumulative excess returns of pension sponsors and non-sponsors based on industry-adjusted returns. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

turnover, and are more unionized. For all R&D specifications, mean differences are statistically significant.

Panel B presents CER of sponsors and non-sponsors based on industry-adjusted returns.[g] Like Panel A, it shows significant differences in returns across all industries.

Table 9 reports results from Eqs. (7)–(9). The pension choice column reports that large firms are more profitable, have a lower market-book ratio, are high in

[g] In addition, we carry several additional analyses between sponsors and non-sponsors. We analyze CER based on the Fama–French industry classification (industry adjusted returns calculated for two and three digits SIC as well as Fama–French 12, 30, and 48 industry classifications). We analyze the industry-adjusted alphas by regressing annualized CER on Fama–French three and five factors. Finally, we also analyze long-run CER and volatility. We always find a significant difference between pension sponsor and non-sponsors (results are available upon request).

Table 9. Heckman's self-selection model.

Variables	Pension choice	Pension size
Lsize	0.332***	−0.042***
	(0.004)	(0.002)
Market-to-book ratio	−0.199***	−0.001
	(0.008)	(0.003)
ROA	0.380***	−0.225***
	(0.075)	(0.027)
Leverage	−0.131**	−1.170***
	(0.060)	(0.017)
Tangibility	0.353***	0.036***
	(0.032)	(0.010)
Assets maturity	−0.002*	−0.001**
	(0.001)	0.000
Z-score indicator	0.195***	−0.142***
	(0.026)	(0.007)
Earnings volatility	−3.033***	−0.105*
	(0.188)	(0.059)
Dividend yield	3.643***	0.570***
	(0.306)	(0.087)
Tenure		0.942***
		(0.214)
Union	−0.145	
	(0.190)	
Constant	−2.240***	1.173***
	(0.091)	(0.033)
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	
Observations	46,342	16,129
Diagnostics		
Wald test: All coefficient = 0 (χ^2)		6792.12***
Heckman's lambda		−0.171***

Notes: This table presents the results of pension plan choice and plans size from Heckman's self-selection model. Pension choice takes a value of 1 for a pension sponsoring firm and 0 otherwise. In the pension size regression, the pension size ratio is the dependent variable. In addition to firm characteristics, we use Union and Tenure variables in the self-selection model. All variables are described in the Appendix. Robust standard errors are reported in parenthesis. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

tangibility, have higher *Z-score*, have higher dividend yields, and are more likely to become sponsors. Interestingly, the coefficient of *Union* variable is statistically not significant, suggesting the decreasing bargaining influence of labor unions across U.S. industries.

Variables commonly used in the capital structure literature tend to significantly influence a firm's pension choice: this is in line with our assumption that pension obligations share many features with long-term debt (Shivdasani & Stefanescu 2010). A firm's pension size is positively linked with employee tenure.

Table 10. Treatments effects estimations.

	Dependent variable: CVW			Dependent variable: CEW		
Variables	Treatment effects	Firm F.E.	Pooled OLS	Treatment effects	Firm F.E.	Pooled OLS
DPB	0.017***	0.030***	0.024*	0.017***	0.031***	0.03
	(0.005)	(0.011)	(0.013)	(0.005)	(0.012)	(0.022)
[PBO/(PBO+total debt)]	−0.056**	−0.028***	−0.086***	−0.039*	−0.048***	−0.161***
	(0.029)	(0.009)	(0.021)	(0.021)	(0.009)	(0.052)
Lsize	−0.021***	−0.041***	−0.056***	−0.018***	−0.115***	−0.142***
	(0.006)	(0.004)	(0.014)	(0.006)	(0.004)	(0.018)
Market-to-book ratio	0.073***	0.099***	0.115***	0.076***	0.122***	0.141***
	(0.003)	(0.003)	(0.005)	−0.002	(0.003)	−0.01
ROA	0.491***	0.556***	0.492***	0.534***	0.617***	0.489***
	(0.034)	(0.026)	(0.061)	(0.032)	(0.028)	−0.082
Leverage	−0.428***	−0.498***	−0.962***	−0.337**	−0.502***	−1.365***
	(0.156)	(0.056)	(0.146)	(0.136)	(0.060)	−0.295
Tangibility	−0.023**	−0.004	0.0000	−0.023**	−0.002	(0.012)
	(0.010)	(0.018)	(0.024)	(0.010)	(0.019)	−0.04
Assets maturity	0.003***	0.002***	0.001**	0.003***	0.000	0.000
	(0.000)	(0.001)	(0.001)	0.000	(0.001)	−0.001
Z-score indicator	0.012	0.012	−0.025	0.026	0.031***	(0.058)
	(0.020)	(0.011)	(0.026)	(0.017)	(0.012)	(0.042)
Earnings volatility	0.087	0.180***	0.066	0.077	0.290***	0.066
	(0.063)	(0.055)	(0.090)	(0.062)	(0.059)	(0.109)
Dividend yield	−1.256***	−1.260***	−1.187***	−1.387***	−1.674***	−1.467***
	(0.104)	(0.128)	(0.341)	(0.124)	(0.138)	(0.371)
Constant	0.145	0.208***	0.562***	0.142	0.783***	1.478***
	(0.171)	(0.061)	(0.152)	(0.139)	(0.065)	(0.301)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	46,342	40,223	46,342	46,342	40,223	46,342
Diagnostics						
R-squared within			0.09			0.09
AR(1)		−0.16			−0.17	
Wald test: all coefficient = 0 (χ^2)	15,545.64***			14,583.77***		
Heckman's lambda	−0.013**			−0.012*		

Notes: This table presents the regression estimates for CER, value- and equally-weighted. Treatment effects estimations are obtained using the two-step treatment model. Bootstrapped standard errors are reported in parenthesis. Firm fixed-effects results are obtained from a pooled OLS regression. Standard errors, robust to heteroskedasticity, and serial correlation are reported in parenthesis. AR(1) presents the estimated first-order auto-correlation coefficients. The pooled OLS model adopts the fixed-effect method. Standard errors are computed using the Driscoll–Kraay (1998) method to address any cross-sectional and intertemporal dependency among error terms. In the treatment model, the pension size ratio is the predicted pension size obtained from the pension size regression. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$ denote the significance levels.

However, profitability influences pension choices, while the large size of PBO outweighs that advantage (see Rauh 2006). Finally, Heckman's lambda is negative and significant at the 1% level: the error terms in the pension choice and pension size model are negatively correlated.

Using predicted values, we analyze the treatment effects as reported in Table 10. By including both firms' fixed effects and pooled OLS regressions, we overcome the sensitivity of instrumental variables (Coles *et al.* 2012) and avoid misspecification issues due to unobserved time-stationary components linked to stock returns.

The treatment effects column shows that an increase in pension size is linked with negative stock returns. The coefficients of pension size for value- and equally-weighted returns are −0.056 and −0.039, respectively. The coefficients for the pension size variable in pooled OLS and fixed-effects models are −0.028 and −0.086 for equally-weighted excess returns, −0.048 and −0.161 for value-weighted excess returns. We, therefore, support earlier evidence: investors partially substitute stock returns for increases in pension size.

As a final additional robustness test, we use patents as an alternative proxy for innovation since R&D expenditure is prone to a high level of missing data. We use firm-level patent data from Stoffman *et al.* (2019) and Kogan *et al.* (2017), scale patents by total assets for each firm, and then sort them into quintiles based on market capitalization portfolios. Results, omitted for space reasons and available upon request, suggest once more that the negative relationship between pension size and returns for innovative firms is strong.[h]

6. Conclusions

In this paper, we study the relationship between firms' stock returns and their sponsorship of defined benefit pension plans for R&D sorted portfolios. This study provides new evidence and quantifies the impact of information asymmetry in stock returns arising from off-balance-sheet items. We assume that, as off-balance sheet items, pension benefit obligations are similar to long-term debt but provide more reporting opaqueness.

We use an extended and large sample of 2541 U.S. pension sponsored firms for the period 1985–2017 and find that R&D-intensive firms that increase pension size subsequently underperform their benchmark returns. Moreover, the pension size potentially drives statistically significant negative returns for low market capitalization and high R&D-intensity firms. The negative benchmark-adjusted returns remain highly significant for high R&D-intensive firms over a long horizon.

Our findings, robust to different methodological approaches, specifications, and alternative proxies, support the hypothesis that investors underreact to firms' decisions to increase pension liabilities. This negative relationship between stock returns and pension size for high R&D-firms is independent of risk and firm characteristics. We do not find a significant relationship for D.B. sponsors with low levels

[h] Omitted for space reasons but available upon request, we empirically verified that financial constraints (Hoberg & Maksimovic 2015), as firms prioritize debt funding (Myers 1984), impact the R&D-corporate pension and stock performance relationship. Consistently with Rauh (2006) with capital expenditures, our main finding is aggravated for firms that issue equity to overcome liquidity constraints.

of R&D. We also find that this relationship is aggravated for smaller firms with high R&D levels.

Therefore, we contribute to the literature on corporate pension plans and R&D by presenting evidence on the negative stock return implications of pension plans for R&D-sorted portfolios.

This study bears some limitations that future research may try to overcome. Whereas stock returns are time-variant, pension sponsorship is not: despite robustness checks, this particular nature of data could bias our results. Additionally, this study does not address the causal relationship between R&D expenditure of plan sponsors and stock performance. Finally, an exciting direction for future theoretical and empirical research could encompass potentially different firm and market responses in the case of defined contribution schemes.

Appendix A

This table provides the reference literature and definition of the variables used in the empirical analysis.

Variable	Reference	Definition and data source
Consolidated leverage	Shivdasani & Stefanescu (2010), Lin *et al.* (2019)	Total debt plus projected benefit obligation scaled by the total market value of the firm.
Funding status	Rauh (2006)	Calculated by subtracting pension plan assets from the projected benefit obligations, divided by projected benefit obligations.
Overfunding	Lin *et al.* (2019)	A dummy variable taking the value 1 if the funding status is positive and 0 otherwise.
Underfunding	Lin *et al.* (2019)	A dummy variable taking the value 1 when the funding status is negative and 0 otherwise.
Pension size ratio	Shivdasani & Stefanescu (2010)	Projected benefit obligation divided by total debt plus projected benefit obligation. $\frac{\text{PBO}}{\text{PBO+total debt}} = \frac{\text{pbpro}}{\text{pbpro+dlc+dltt}}$
Dividend yield	Kisser *et al.* (2017)	Common and preferred stock dividend divided by the market value of equity.
Assets maturity	S. Myers (1977)	Book value of the weighted average of the maturities of property, plant, and equipment. Calculated as the gross value of PPE divided by total assets times PPE divided by the annual depreciation expense, plus the current assets divided by total assets times current assets divided by the cost of goods sold. Assets maturity $=\left(\frac{\text{ppegt}}{\text{at}}\right) * \left(\frac{\text{ppegt}}{\text{dp}}\right) + \left(\frac{\text{act}}{\text{at}}\right) * \left(\frac{\text{act}}{\text{cogs}}\right)$
Earnings volatility	Huang *et al.* (2016)	The 3 years standard deviation of EBITDA divided by the average assets for that period.
Leverage	Brockman *et al.* (2010)	Total debt divided by the equity market value. Leverage $= \frac{\text{dlc+dltt}}{\text{prcc\_c*csho+at}-\text{ceq}}$

(*Continued*)

Variable	Reference	Definition and data source
Market-to-book ratio	Shivdasani & Stefanescu (2010)	The market value of the firm divided by the book value of the total assets.
ROA	Myers & Majluf (1984)	The operating income before depreciation divided by the total assets.
Lsize	Diamond (1991)	Logarithm of market value of the firm.
Tangibility	Demirci *et al.* (2019)	The gross property, plant, and equipment divided by the book value of total assets.
Z-score	Brockman *et al.* (2010)	Altman's Z-score dummy, equaling 1 if $Z > 1.81$.
R&D expenditure	Croce *et al.* (2019)	Annual research and development expenditure divided by the book value of total assets.
R&D capital	D. Li (2011)	The weighted average annual R&D ratio over total assets over the past 5 years. $\mathrm{RDC}_{\mathrm{it}} = \mathrm{R\,\&\,D}_{\mathrm{it}} + 0.8 * \mathrm{R\,\&\,D}_{\mathrm{it}-1} + 0.6 * \mathrm{R\,\&\,D}_{\mathrm{it}-2} + 0.4 * \mathrm{R\,\&\,D}_{\mathrm{it}-3} + 0.2 * \mathrm{R\,\&\,D}_{\mathrm{it}-4}$
Patent	Stoffman *et al.* (2019), Kogan *et al.* (2017)	We scale the total value of patents by total assets for each firm-year and then sort in quintiles based on market capitalization portfolios.
Union	Shivdasani & Stefanescu (2010), Lin *et al.* (2019)	Union affiliation data obtained from the Current Population Survey, representing the share of employees that are unionized.
Tenure	Shivdasani & Stefanescu (2010), Lin *et al.* (2019)	Median years of tenure with current employer for employees by industry (U.S. Bureau of Labor Statistics).

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